General Specification for Development of the DFM Cask

for the

Multi-Axis Crystal Spectrometer (MACS)

National Institute of Standards and Technology

Center for Neutron Research

Revision 4a

Timothy D. Pike
MACS Project Engineer
NIST Center for Neutron Research (856)
Building (235), Room B112
100 Bureau Drive, Stop 8563
Gaithersburg, MD 20899-8563
Tel: (301) 975-8373
Fax: (301) 975-4528
email: tpike@nist.gov

1. Overall Specifications

The MACS monochromator cask contains all elements associated with controlling the neutron illumination and the location of the doubly focusing monochromator for MACS. The neutronic input is a diverging cold neutron beam with a circular cross section. The neutronic output is a converging, monochromatic neutron beam trimmed to a rectangular cross section and emanating in a specific direction from a specific location along the incident beam line.

1.1 Bounding box dimensions

The entire cask shall fit into the overall bounding box described in Figures 1-8 and through the solid body in the accompanying IGES file. No clearance beyond those dimensions can be guaranteed. The IGES file also indicates internal exclusion zones where the only permissible content apart from helium shall be the DFM.

1.2 Materials requirements

Windows through which the neutron beam will propagate shall be made from 1100 aluminum and have a thickness that is to be minimized and that shall not exceed 2 mm. There is an overall requirement that to the extent practical all volume within the cask that is not occupied by fixed beam optics elements, required for moving optics travel, and that does not lie within exclusion zones defined in the 3D solid body shall be filled with bulk shielding material. There are additional materials requirements indicated on the accompanying drawings. Materials types employed are listed below:

1. Structural Aluminum 6061-T6
2. Structural Steel
3. Pure Aluminum alloy 1100
4. ^{10}B:Al (1mm or 6mm sheet stock)
5. Bulk shielding material: 55% (volume fraction) steel shot in 45% wax held in a closed steel containment vessel.
6. Laminations of high density polyethylene and Steel

1.3 Shielding & Construction Considerations

Six functional element types determine the Cask volume:

1. Helium containing shell
2. Neutronic devices (DFM, ICX, VBA)
3. Neutronic device swept volumes (DFM, ICX, VBA)
4. Beam path
5. Beam windows
6. Shielding

The construction of the external surfaces that the cask presents shall be generally smooth and developed from primary solid volumes. External protrusions greater than 2mm shall be minimized. Volumes within the cask greater than 10cm^3 that are not associated with the optics or beam path and that are not part of an exclusion zone shall be filled with shielding.

1.4 Attachment to MACS

The Cask shall be fully self-supporting on a horizontal surface that has a vertical location tolerance of ± 10 mm. The nominal distance from this surface to beam height shall be determined by the cask sub-project and minimized within the constraints defined by 1.1. This is the only dimension of the bounding box that is under control of the subproject. The chosen dimension shall be reported back to the project engineer. Fixtures and/or profile required on this surface are to be defined by the cask sub-project and reported back to the project engineer. Installation and removal of the cask and its components shall be possible using an overhead crane. During this process a clearance on all sides of 10 mm with respect to the bounding box dimensions can be assumed.

1.5 Alignment process

The relative alignment of the ICX, VBA, and DTS within the cask shall be performed optically and/or mechanically to within the tolerances described below. Internal alignment and verification of such is the responsibility of the sub-project. The internal alignment shall remain true following removal and re-installation of the ICX, VBA, or DFM. Adjustment capabilities shall be devised so that the cask or a set of mounting points that it rests on can be accurately aligned with respect to the incident beam line using standard optical techniques. The adjustment range required relative to the horizontal mounting surface on MACS will be ±10 mm in all directions. Overall cask alignment with respect to MACS shall ensure that the cask central axis coincides with the MACS central axis to within ±1 mm in the horizontal plane and ±2 mm in the vertical plane. This alignment shall remain true upon removal and subsequent reinstallation of the cask. The process of removing and then reinstalling the cask from and then back to an aligned condition shall be as simple as reasonably achievable.

2. Internal Functionality

Table 1 specifies the locations of neutronic components along the MACS beam line as well as the conical incident neutron beam profile. Details on the functionality of all beam line elements are provided in separate specifications that are or will be accessible via the project web site at http://www.pha.jhu.edu/~broholm/MACS/ . In the following we focus on internal cask interfaces.

2.1 Helium Containment

The cask shall hold a low positive pressure of helium to reduce neutron scattering losses and minimize radioactive argon production that would be incurred in an air environment. The cask is not intended to be a high integrity sealed vessel, rather it is a semi-permeable structure that presents a low (<0.01 cfm) leak rate to the helium source. There shall be two helium access ports on the top plate of the cask close to the locations indicated on Figure 5. Feed lines shall be detachable and the interface radiation hardened. The specifications for these interfaces shall be devised by the sub-project and provided to the project engineer.

2.2 In Line Collimator Exchanger (ICX)

Overall requirements for the ICX are provided at http://www.pha.jhu.edu/~broholm/MACS/archive.htm. The development specification for the ICX will be provided under separate cover. The ICX shall be vertically actuated by means of pneumatic cylinders supplied with shop air (100 psi). Seals for the shaft penetration into the cask shall be radiation resistant and provide a 5-year nominal life. Cask wall segments shall be provided that will allow removal of the ICX along a vertical line of travel. Detachment and removal of the ICX vertically from the cask shall be possible without requiring that human body parts enter the cask. The central axis of the ICX shall coincide with the cask beam line axis to within 0.05^{o} and 1 mm at the location of the device. The location of the ICX along the beam line shall be consistent with 1.1 and with the information in table 1 to within 1 mm translation along the beam axis. When the DFM is rotated to face the ICX, the central axis of the ICX shall intersect the center of the DFM to within $\pm$0.5 mm horizontally and $\pm$1 mm vertically.

2.3 Variable Beam Aperture (VBA)

Overall requirements for the VBA are provided at http://www.pha.jhu.edu/~broholm/MACS/archive.htm . The development specification for the VBA will be provided under separate cover. VBA actuation and position sensing shall be completely contained within the cask. The centerline of the VBA shall lie on the cask beam centerline to within 0.5 mm. The plane of the aperture shall be normal to the central axis of the cask to within 2^{o}. The location of the VBA along the beam line shall be consistent with 1.1 and with the information in table 1 to within 1 mm translation along the beam axis. Cask wall segments shall be provided that allow removal of the VBA along a vertical line of travel. Detachment and removal of the VBA from the cask shall be possible without requiring that human body parts enter the cask. Cable exits shall be combined with DFM cables to exit the cask at a common bulkhead feature on the top plate.

2.4 DFM Transport System (DTS)

Overall specifications for the DTS and the DFM are available at http://www.pha.jhu.edu/~broholm/MACS/archive.htm . The DTS provides precision remote controlled translation of the DFM along the beam axis. As for all other elements within the cask, the DTS system shall be designed to minimize void space for maximum utilization of neutron shielding materials.

2.4.1 Actuation

The DTS shall be a direct drive mechanical system based on a ball-screw drive. The drive shaft shall exit the cask through a seal that lies at least 100 mm below the beam exclusion zone. The shaft shall terminate with an interface outside the cask, to which a long extension shaft that penetrates the bulk shielding on MACS can connect. It shall be possible to disconnect and reconnect this extension shaft through axial motion only and without access to the interface. The detailed interface shall be defined by the cask sub-project and reported to the project engineer. The extension shaft is not a deliverable for the cask sub-project.

2.4.2 Motor and Encoder

The drive motor will reside in a nominally radiation free environment outside the bulk shielding. The drive shaft shall be fitted with an absolute encoder that also resides outside the bulk shielding. The drive motor and encoder shall be selected by the cask sub-project in consultation with Nick Maliszewskyj. For test purposes the drive motor and encoder shall be connected to the cask shaft using a dummy extension shaft, which mimics the functionality of the bulk shield penetrating extension shaft on MACS.

2.4.3 Range, accuracy, and speed of travel

The range of travel shall be 20 mm beyond that which is required by table 1. This corresponds to 1020 mm up-stream and 607 mm down-stream from reference position for a full travel of at least 1627 mm. There shall be home switches within the cask that are activated at the reference location and at the extreme ranges of travel with $\pm$0.5 mm reproducibility. The DTS shall be capable of providing full travel of the DFM in less than 30 seconds. The positional accuracy for the DTS shall be $\pm$0.5 mm in all directions.

2.4.4 Cable management

A cable management system shall safely propagate cables attached to the mobile DFM system to a stationary bulkhead interface on the cask top plate. The cask and DTS shall be designed such that no crash condition involving the DFM or associated cables is possible when operating the DTS, the DFM rotation, and the DFM translation.

2.4.5 DFM Access

The DFM shall be removable and re-mountable from a specific location along the travel path. Cask access segments shall be provided that will allow removal of the DFM along a vertical line of travel. Detachment and removal of the DFM from the cask shall be possible without requiring that human body parts enter the cask.

2.4.6 Lifetime and Maintenance

The motive and bearing systems shall allow for 100,000 full travel cycles for the DFM over the anticipated device life of 20 years. Lubricants shall be selected to be unaffected by the high radiation environment for the life of the unit (or specific scheduled maintenance in not less than 3 year intervals).

2.5 Beam Entrance and Exit

The DFM cask receives the filtered “White” beam from the Cryo Filter Exchanger. The Monochromated beam is directed to the Super Mirror Guide, and the remaining neutrons pass on to the beam dump. To reduce losses and minimize scattering the beam windows shall be constructed from Pure Aluminum (Alloy 1100) and be of minimum thickness.

2.5.1 Beam Entrance

The entering “White” Beam window shall be circular with a diameter of 320mm $\pm$ 5mm at the 3790mm position. Material surrounding the window is beam defining and shall be constructed of neutron absorbing material (^{10}B:Al) with a minimum outer diameter of 400 mm and a minimum thickness of 1 mm.

2.5.2 Beam Exit

Following the monochromator, the beam continues to the beam dump through a beam exit window. The diameter of the window shall be no less than 570mm at the 7000mm position.

2.5.3 Monochromated Beam Exit

Between the DFM and the focal point of the DFM lies the Super Mirror Guide (SMG). The SMG resides within a drum of diameter 900 mm. The cask window conforms to the circular surface of the SMG. The Monochromated beam exit shall be the surface of a 912 mm diameter cylinder, 250 mm tall and traversing 57 degrees up beam and 42 degrees down beam. The center of the cylinder is located 700 mm from the transit axis of the DFM at the reference (90 degrees, 5700 mm) position of the DFM. The SMG fits within the DFM frame near and at the reference position of the DFM. Vertical clearance (10 mm) between the SMG entrance and the DFM assures that interference does not occur. (See Figures 6 and 7)

2.6 Computer control

All functional elements within the cask shall be controlled via the DFM computer. The DFM control computer in turn receives commands from the MACS instrument control computer via an RS232 interface. A communication interface shall be proposed by the cask sub-project and approved by project level review. To the extent possible all communication to and from the DFM control computer shall be in terms of the natural physical dimensions that are involved. For example the DTS should be addressed in terms of the distance from DFM to source as measured in mm.

The following commands shall be included as a minimum:

1. Abort all motion
2. Report the status of motion for any controlled actuator
3. Determine the setting of any actuator controlled by the DFM computer
4. Drive any actuator controlled by the DFM computer to a specified setting
5. Drive any actuator to any of its home positions and check against the encoder if applicable.
6. Select one of the four collimation options
7. Set up the monochromator for monochromatic focusing at a specified energy. The command translates the DFM to the required location, rotates the device, and sets the DFM blades and the vertical focusing as required.
8. Set up the monochromator for non-monochromatic focusing with a specified average scattering angle and overall DFM rotation angle. The command translates the DFM to the required location, rotates the device, and sets the DFM blades and the vertical focusing as required.

Additional requirements and information will be provided in a separate control interface specification.

3. Additional Specifications

Additional specifications will be provided for the following:

- Paint & Finish
- Steel Shot & Wax
- Interfaces to other MACS elements
- Inspection & Test procedures

Project level approval is required for the following;

- Electrical Connectors
- Power & Communications Standards

Project Engineering Contacts

Mechanical & Systems	Timothy Pike	301.975.8373	tpike@nist.gov
Electrical & Software	Nick Maliszewskyj	301.975.3171	nickm@nist.gov

Element	Total Thickness	Local Thickness	x	y	2y	2Y
				Radius	Diameter	Clearance Diameter
Theoretical Beam Convergence Point			-1200	0		
Cold Source Face			0	37.7	75	84
Beam Hole			1654	89.7	179	199
Face of Bio Shield @ Beam C/L			2435	114.2	228	254
Forward Edge of Bio Shield			2600	119.4	239	265
Shutter In			2620	120.0	240	267
Shutter Out			3320	142.0	284	316
Cryo Filter Exchanger		CFX	3330	142.4	285	316
		150	3518	148.3	296.5	330
		100	3625	151.6	303.3	337
	440	80	3712	154.4	308.7	343
		20	3732	155.0	310.0	344
			3770	156.2	312	347
In-line Collimator Exchanger		ICX	3800	157.1	314	349
		140	3940	161.5	323	359
	355		3945	161.7	323	359
		210	4155	168.3	337	374
Variable Beam Aperture		VBA	4165	168.6	337	375
		100	4265	171.7	343	382
	205		4270	171.9	344	382
		100	4370	175.0	350	389
	310		4375	175.2	350	389
		100	4475	178.3	357	396
Monochromator	Leading edge	DFM	4465	178.0	356	396
35°	Axis		4700	185.4	371	412
Total Travel 90°			5700	216.8	434	482
1587 106°			5900	223.1	446	496
130°			6287	235.3	471	523
Beam Dump Window			7000	257.7	515	573
Beam Dump			9691	342.3	685	761

Table 1. Location and transverse dimensions of MACS incident beam line elements

Figures

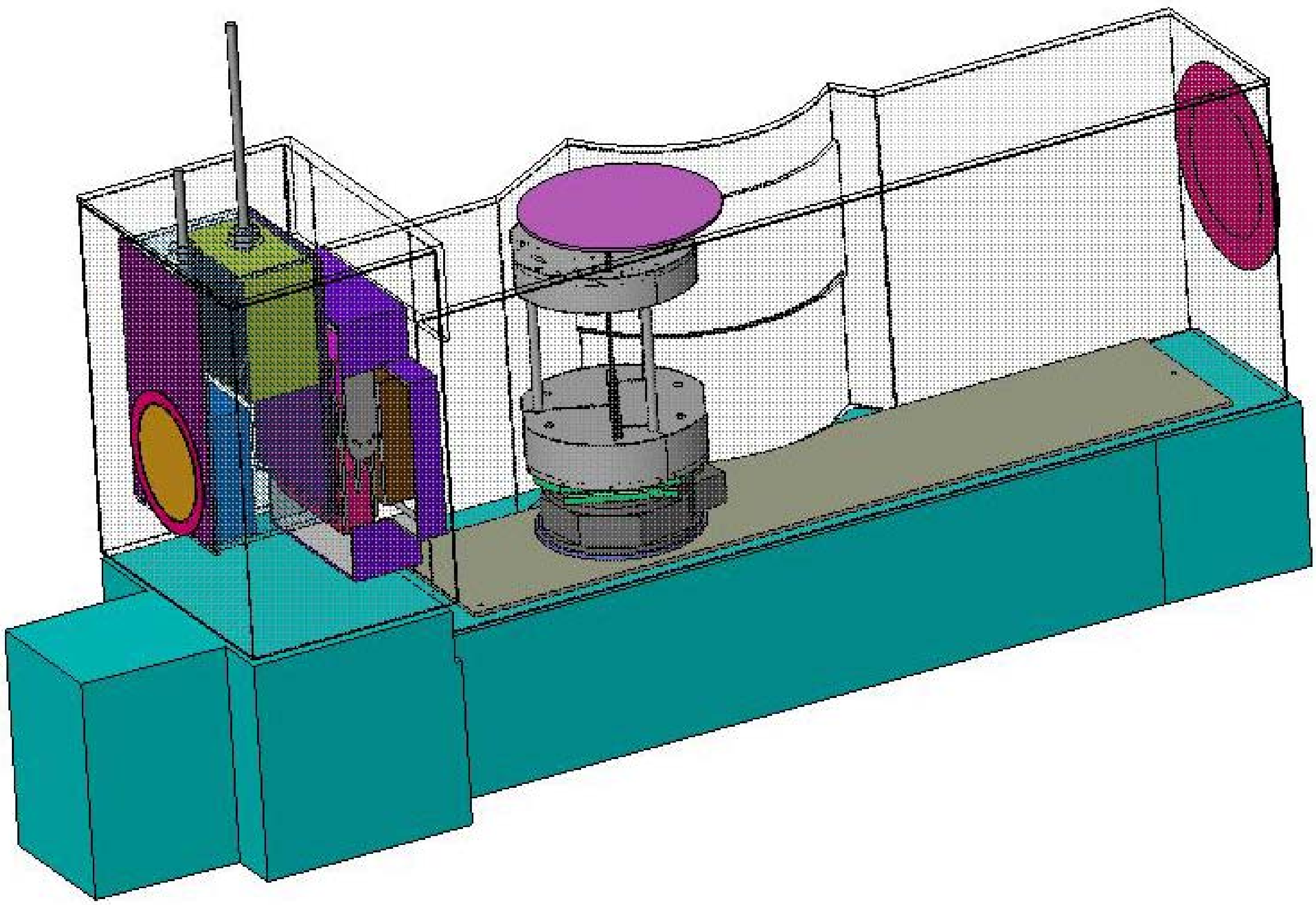


Figure 1 DFM transport, helium cask and VBA concept. The cask bounding box is shown translucent. The teal base is part of MACS and is not supplied by the sub-project.

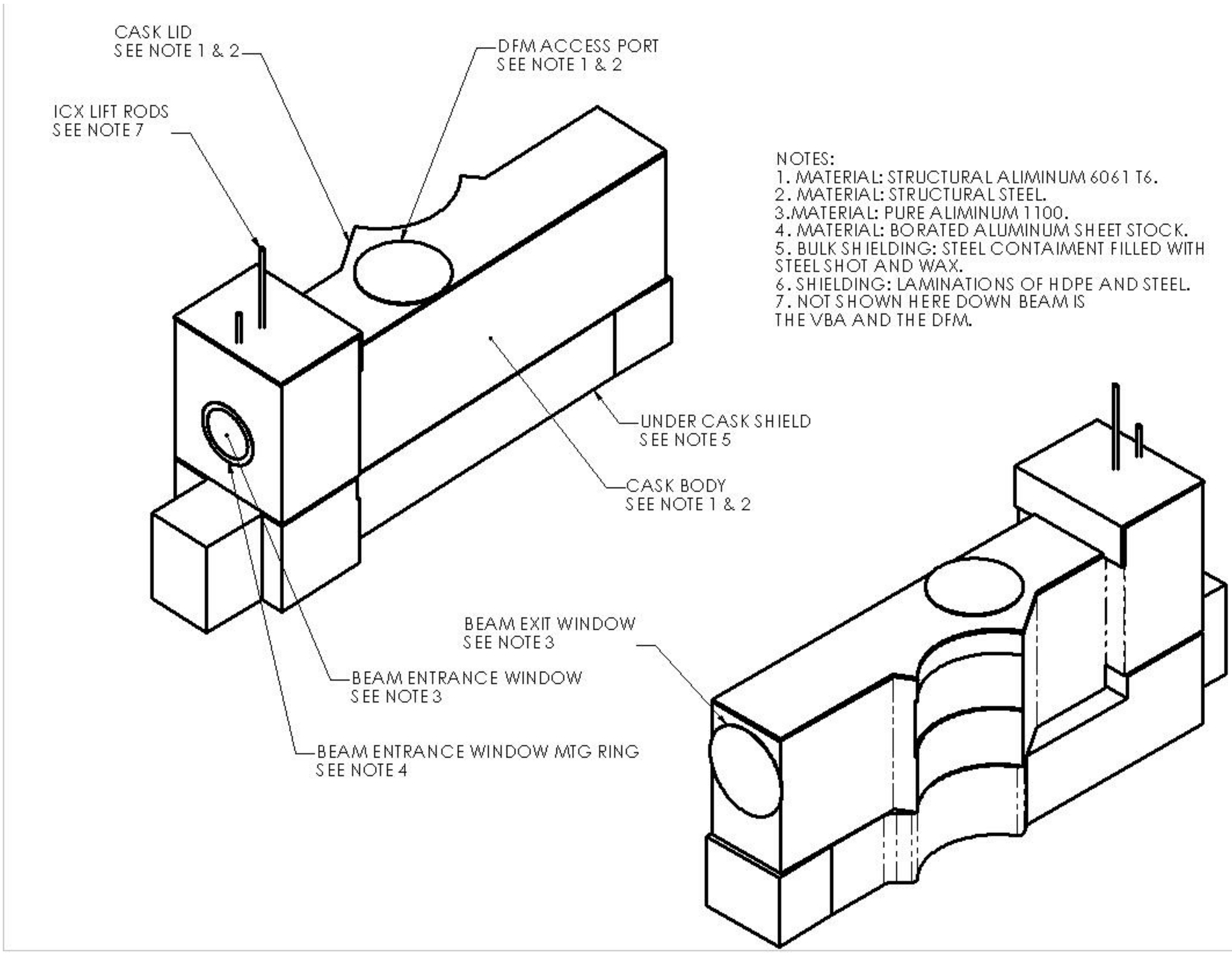


Figure 2 Perspective views of the cask bounding box and mounting surface with materials requirements

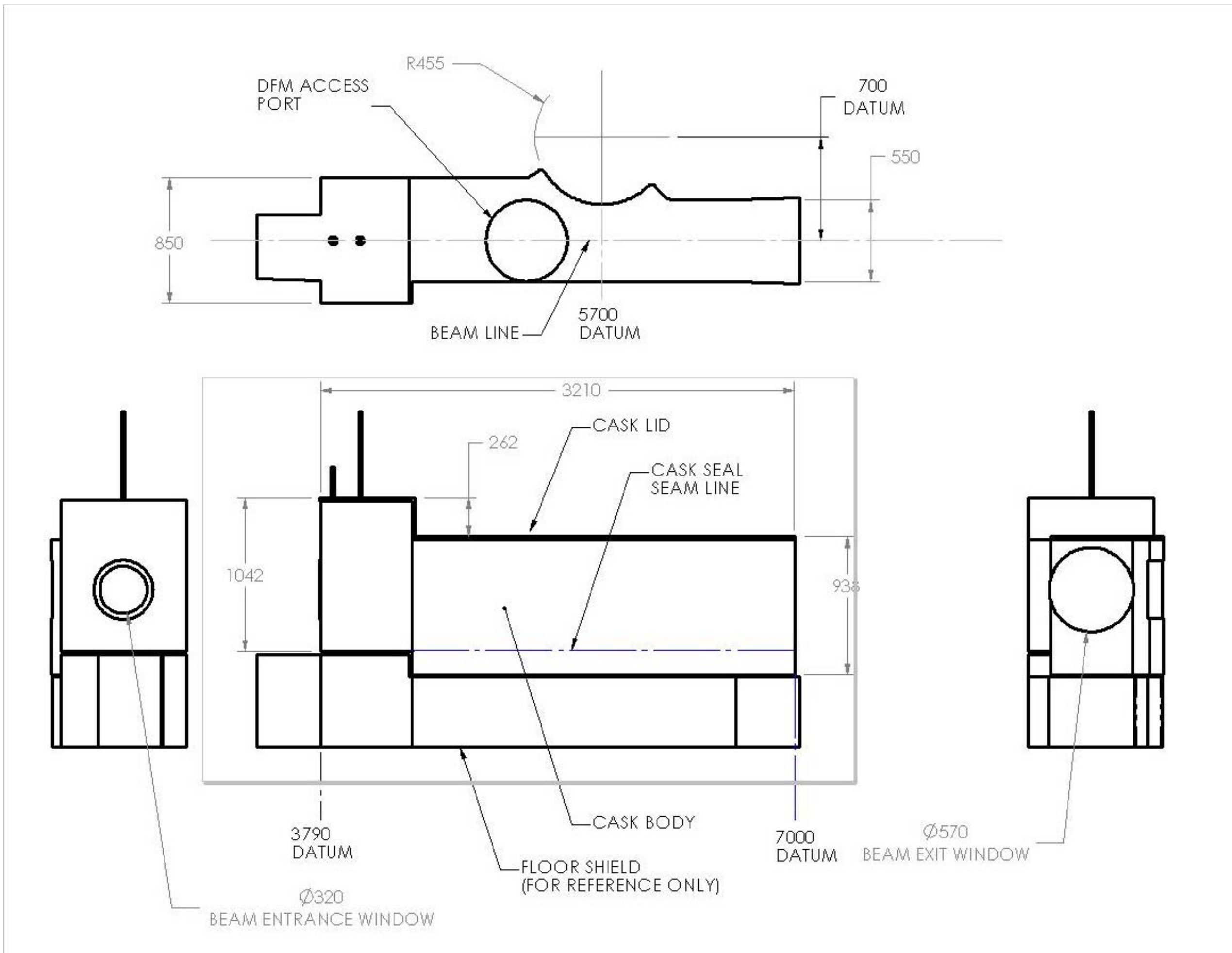
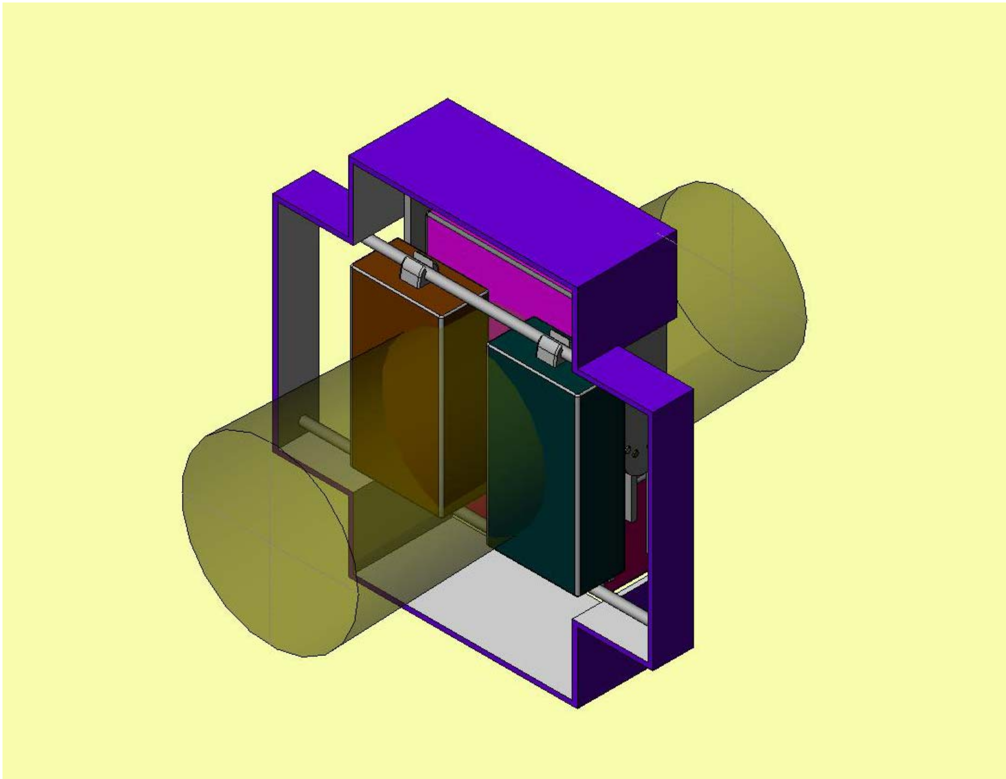


Figure 3 Cask over-all dimensions



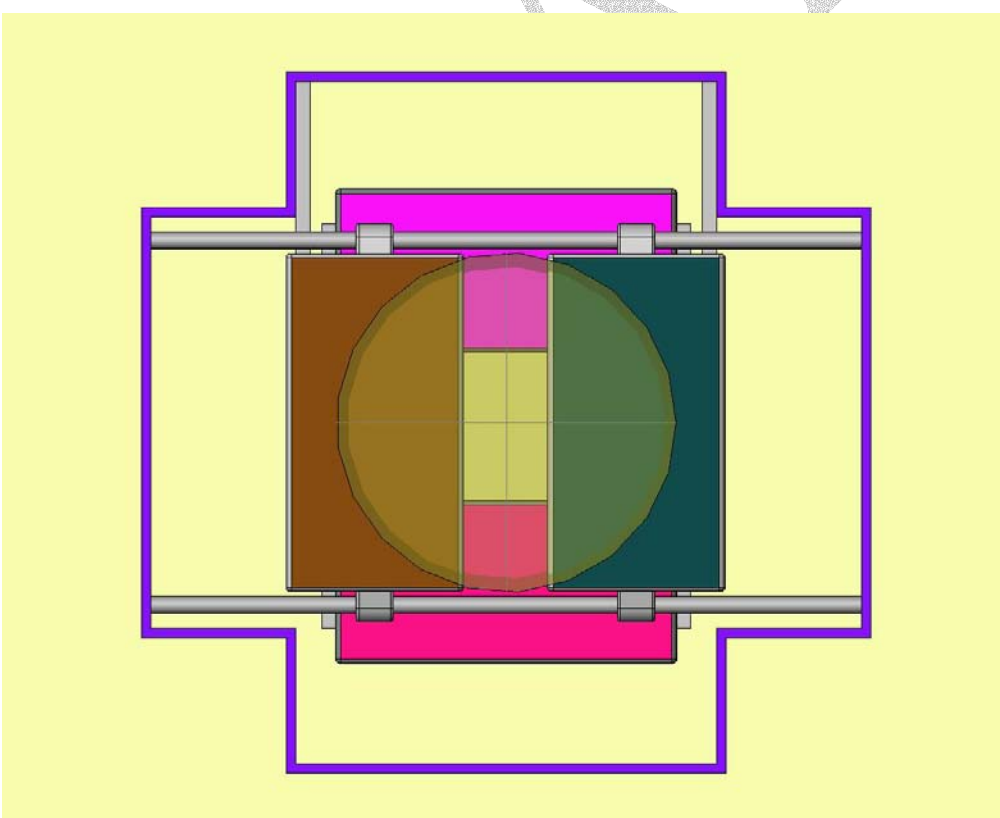


Figure 4 Partially open VBA in perspective view and in front view towards source.

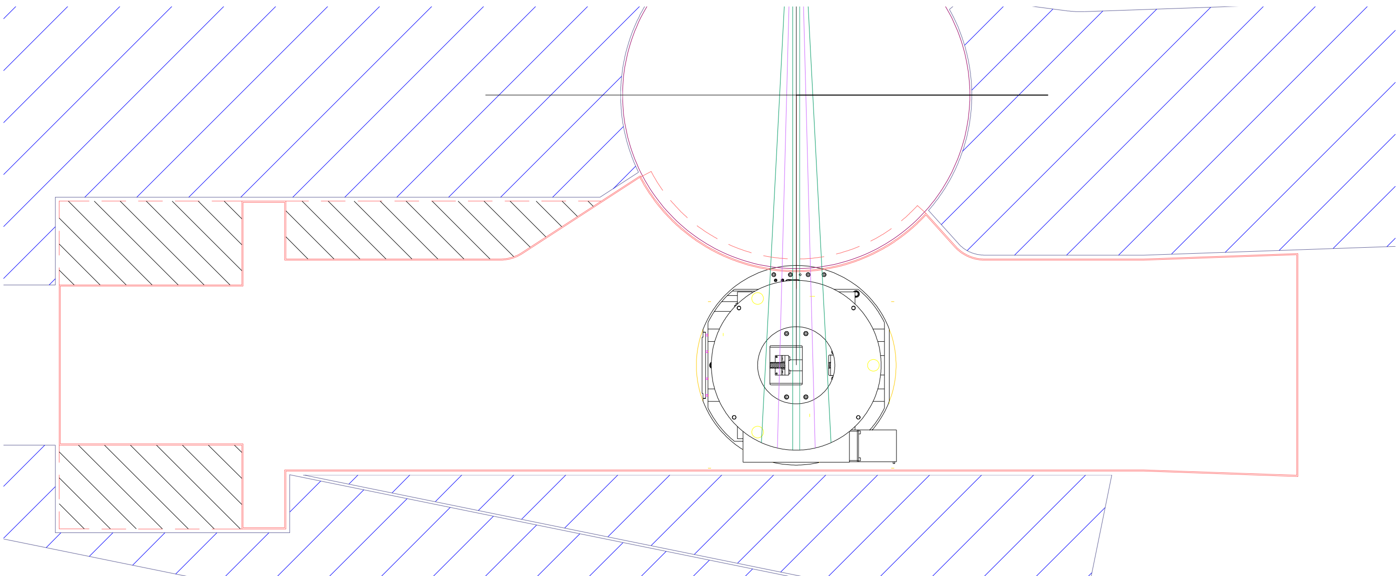


Figure 5 Cask plan view

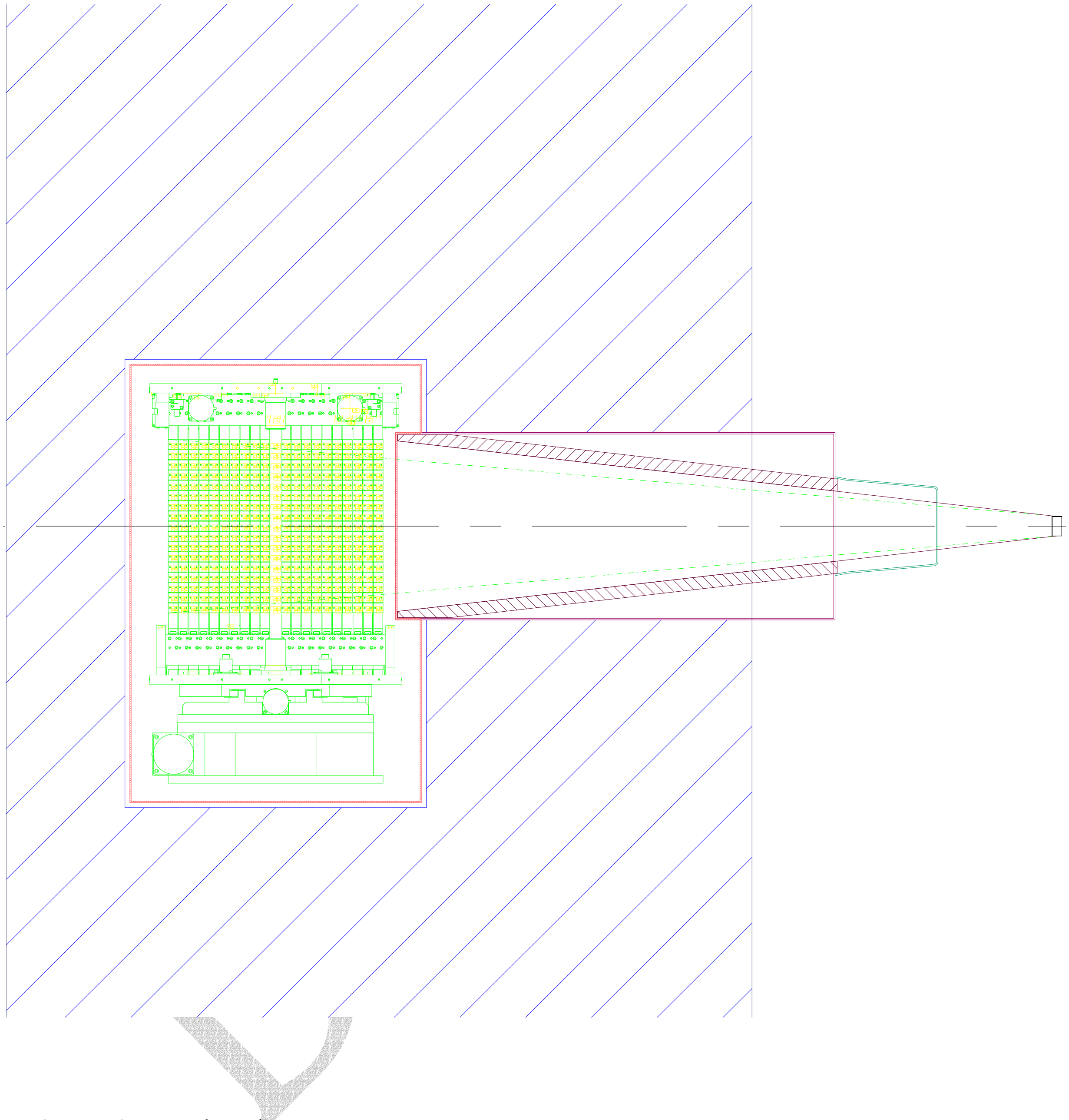


Figure 6 Rear elevation.

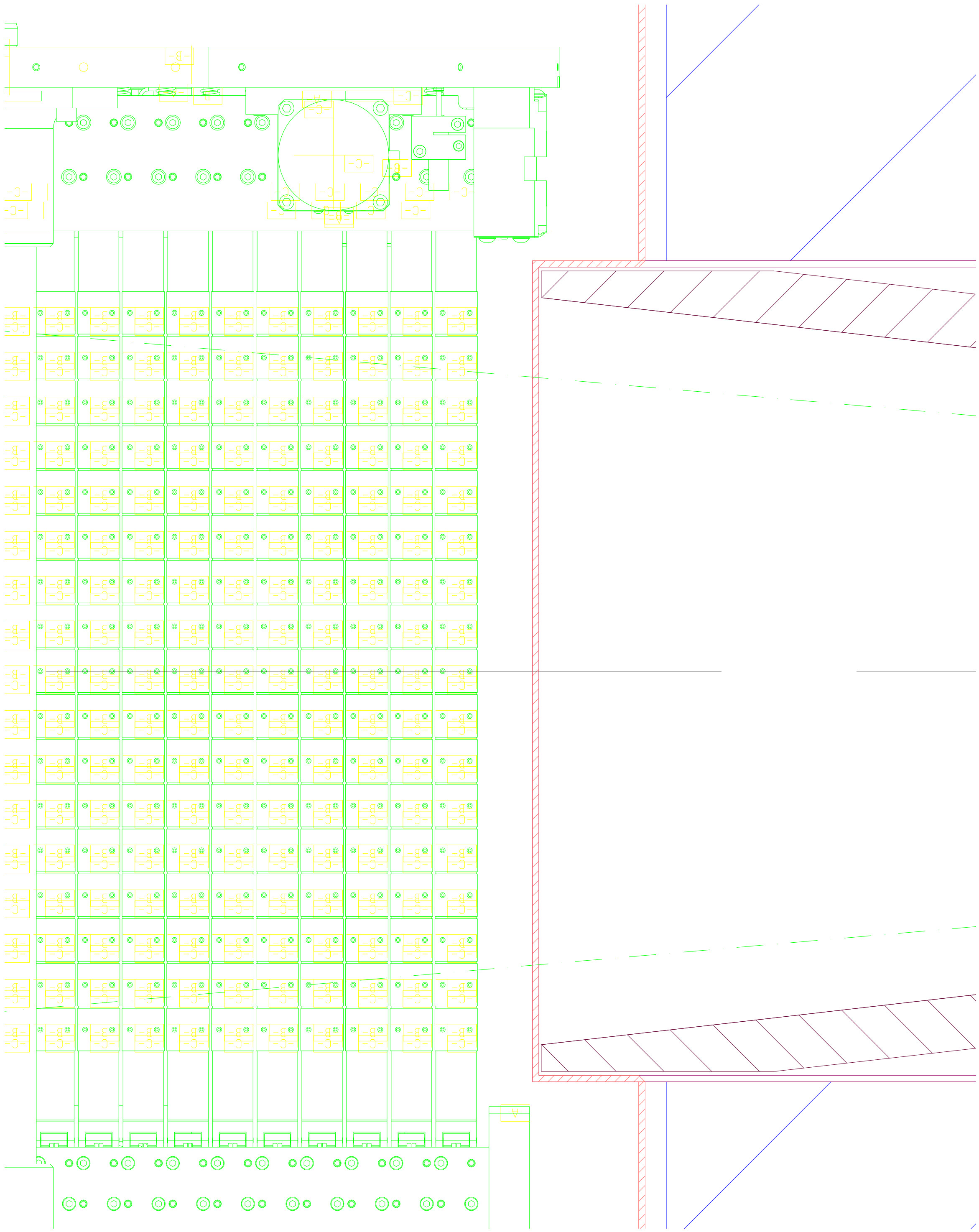


Figure 7 Rear elevation view showing DFM and SMG window details

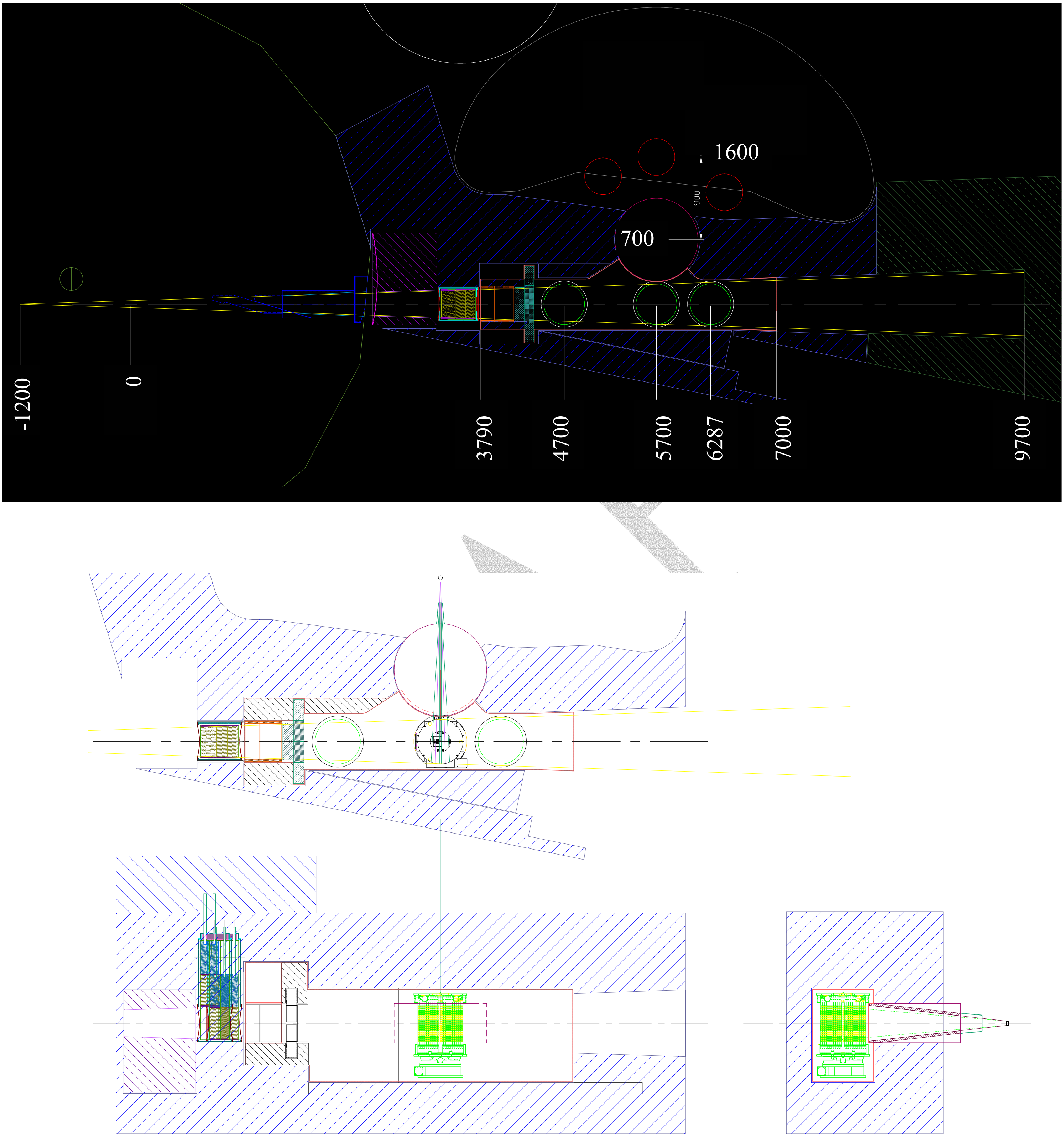


Figure 8 MACS general layout.